Seasonal changes in Titan's weather patterns bring extensive methane rainstorms to Titan's low latitudes

E.P. Turtle, J.E. Perry, A.G. Hayes,
R.D. Lorenz, J.W. Barnes, A.S. McEwen,
R.A. West, A.D. Del Genio, J.M. Barbara,
J.I. Lunine, E.L. Schaller, T.L. Ray,
R.M.C. Lopes, E.R. Stofan

Turtle et al., *Geophys. Res. Lett. 38*, L03203, 2011
Turtle et al., *Science 331*, pp. 1414-1417, 2011

Cassini Mission Overview

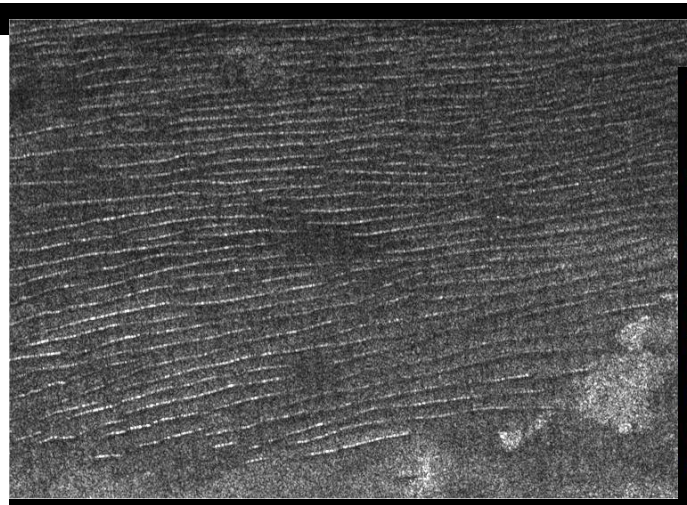
Four-Year Prime Tour, Equinox Mission, and Solstice Mission (Proposed), May 2004 - September 2017

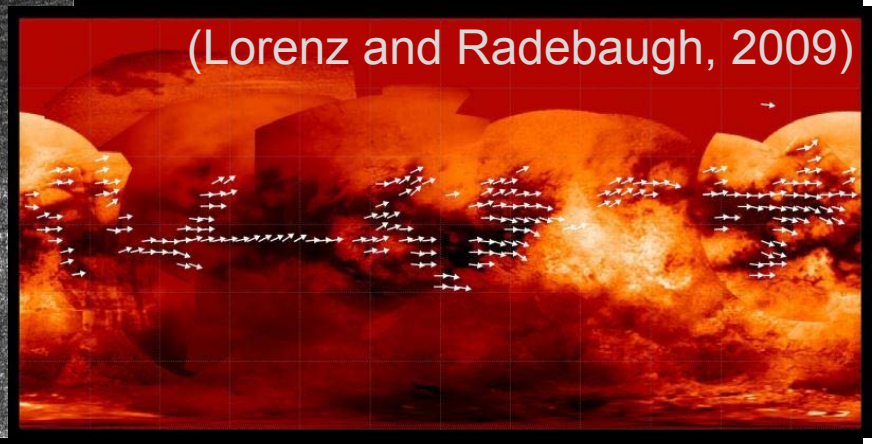
	Prime Mission				Equinox Mission		Solstice Mission						
Year of Tour	1	2	3	4	5	6	7	8	9	10	11	12	13
	'04-'05	'05-'06	'06-'07	'07-'08	'08-'09	'09-'10	'10-'11	'11-'12	'12-'13	'13-'14	'14-'15	'15-'16	'16-'17
Orbits	11	15	22	27	39	21	16	19	25	12	12	20	56
Titan													
*Huygens	*												
Enceladus													
Other Icy Satellites (under 10,000 km)	Phoebe	Tethys, Hyperion, Dione, Telesto, Rhea		Rhea, Iapetus, Epimetheus		Mimas, Rhea, Helene, Dione, G arc	Rhea, Helene	Dione, Dione, Tethys, Methone, Telesto	Rhea		Dione, Tethys	Dione, Epimetheus, G arc	
													Proximal Orbits; EOM Sep 15, 2017

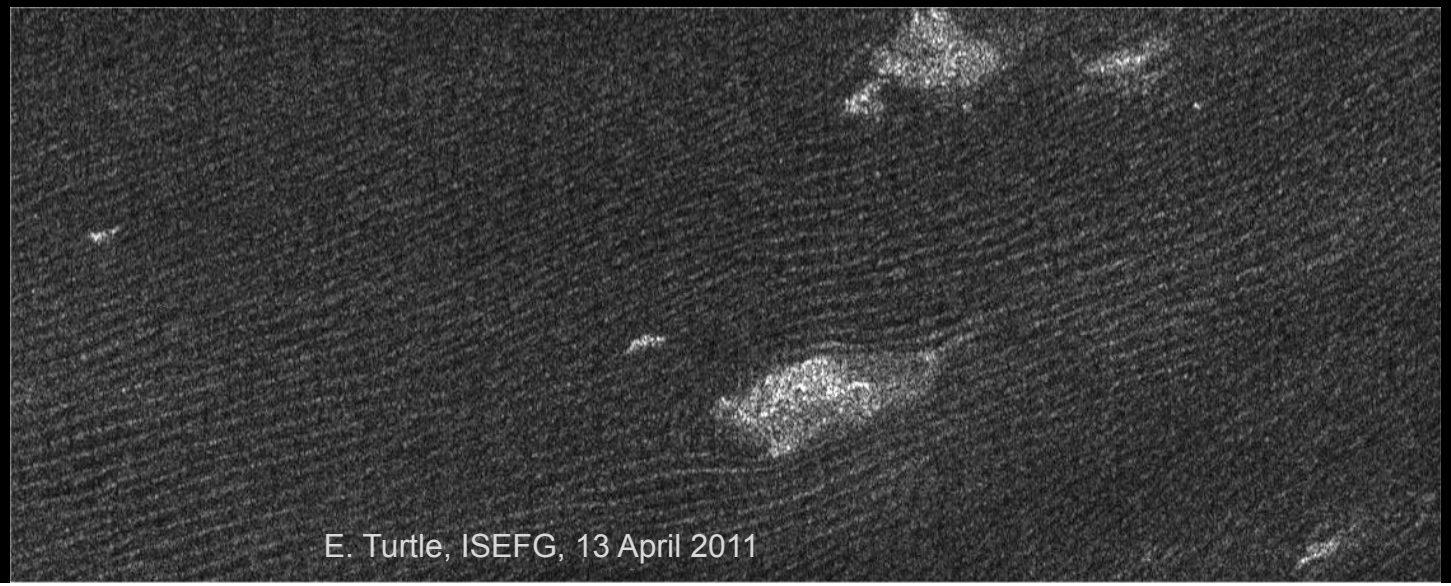
Saturn (seen from Sun)

ISS map of Titan (2010)

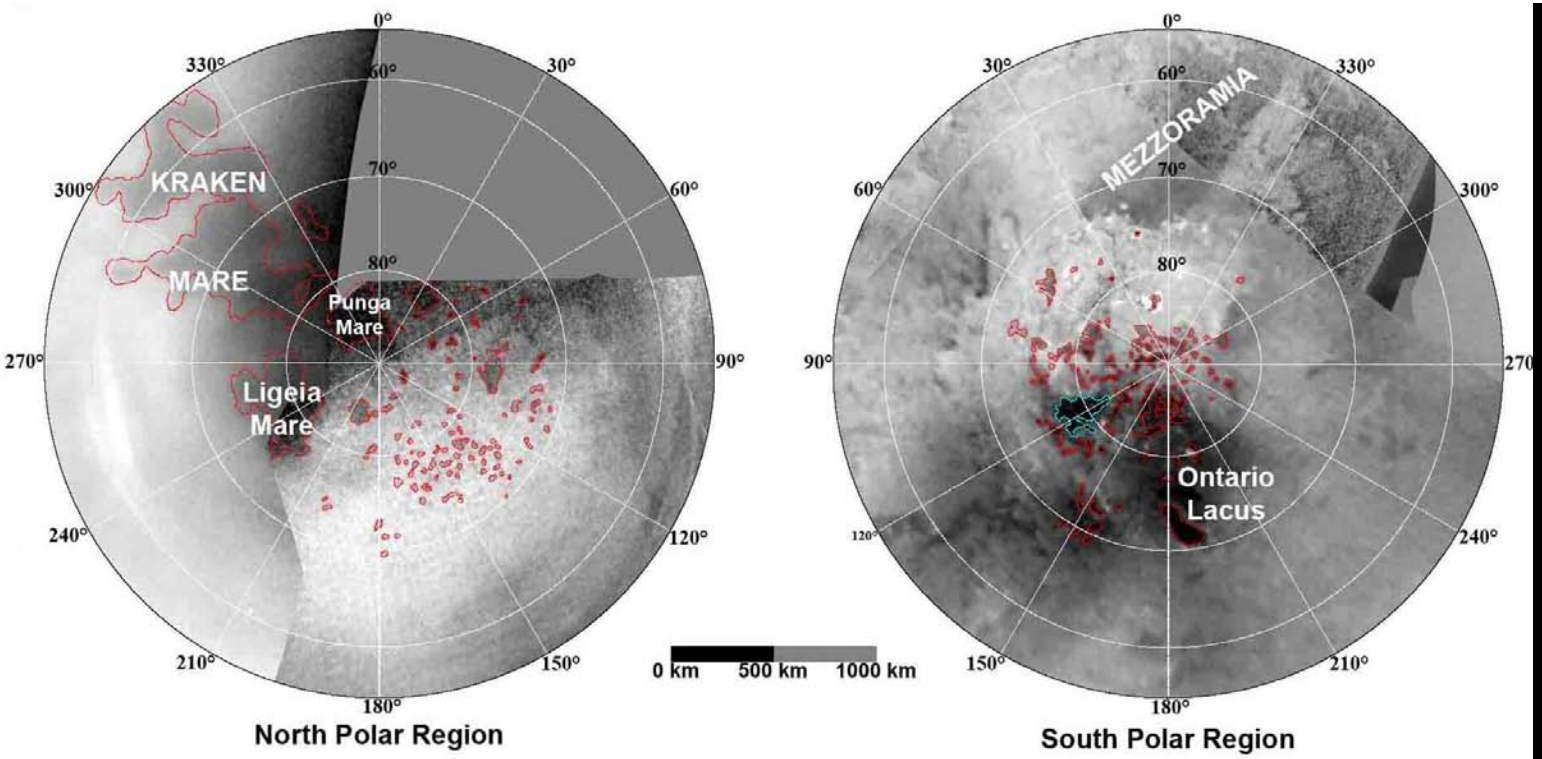
Equatorial Dunes



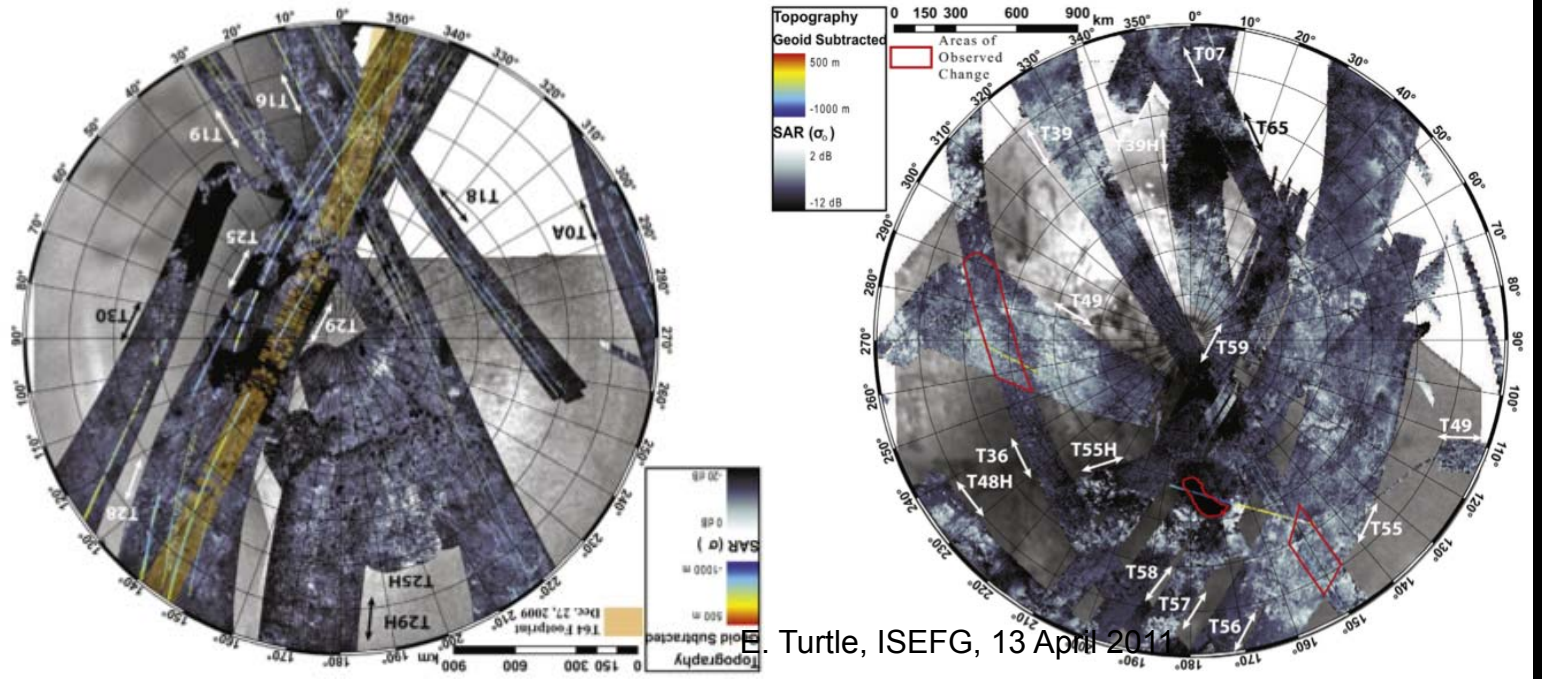




Polar lakes and seas



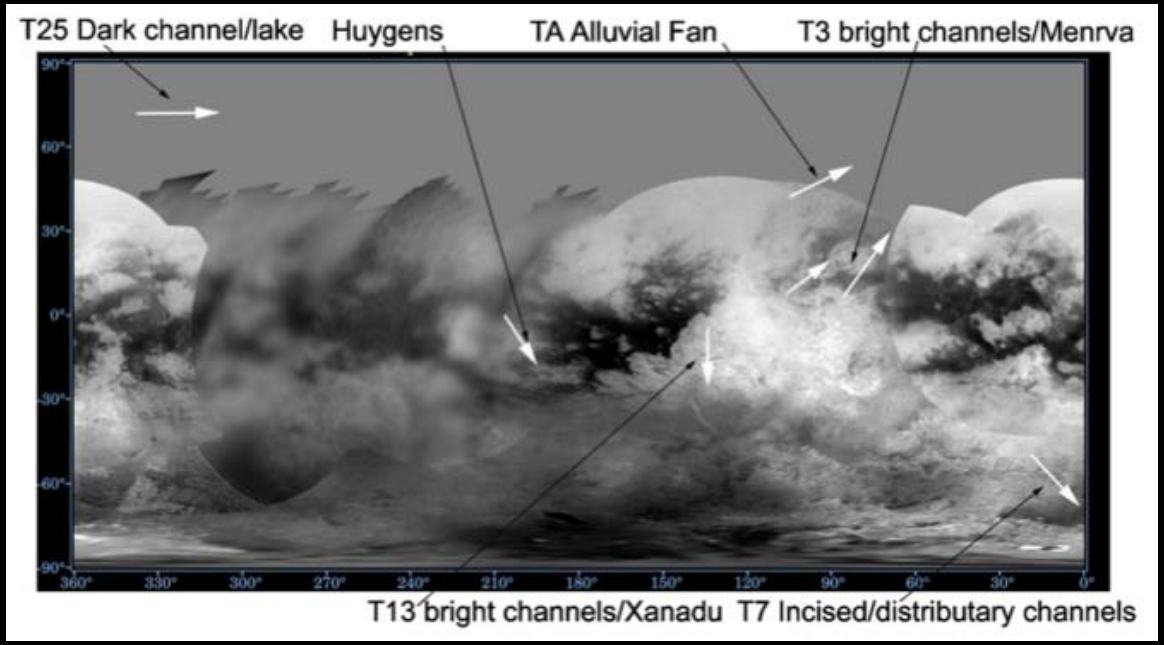
(Turtle et al., 2009)



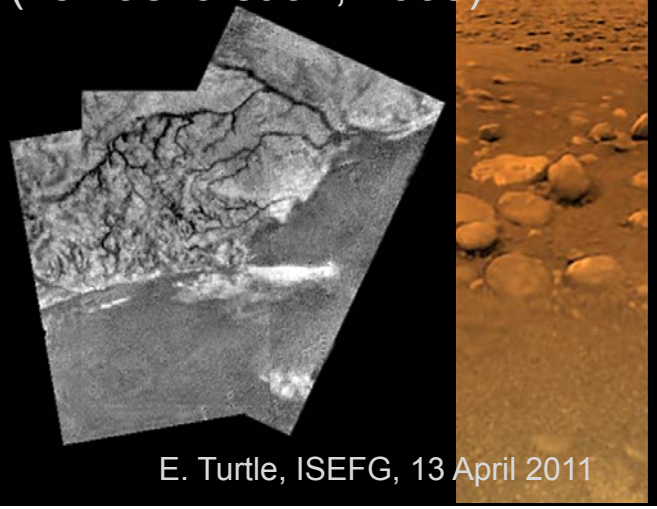
(Hayes et al., 2010)

Channels

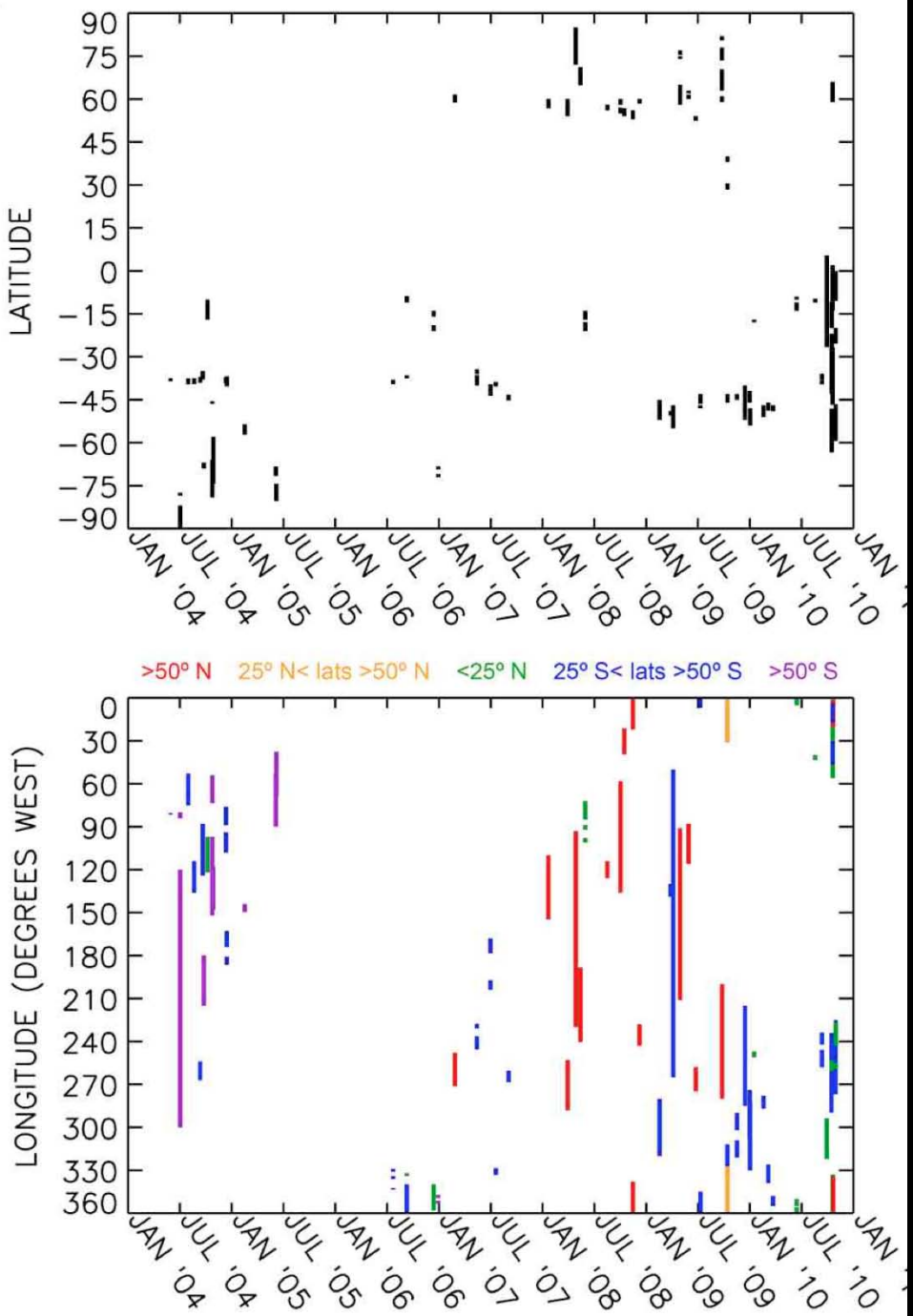
(Lorenz et al., 2008)



(Tomasko et al., 2005)



(Le Gall et al., 2008)

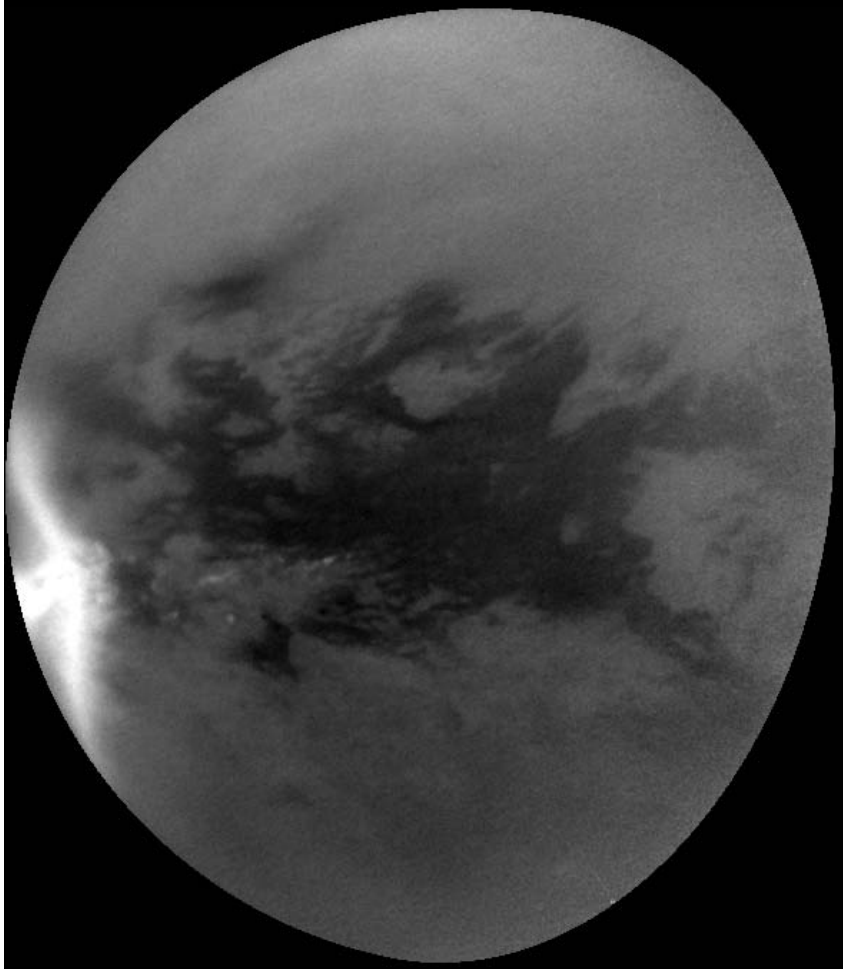


ISS observations of cloud locations

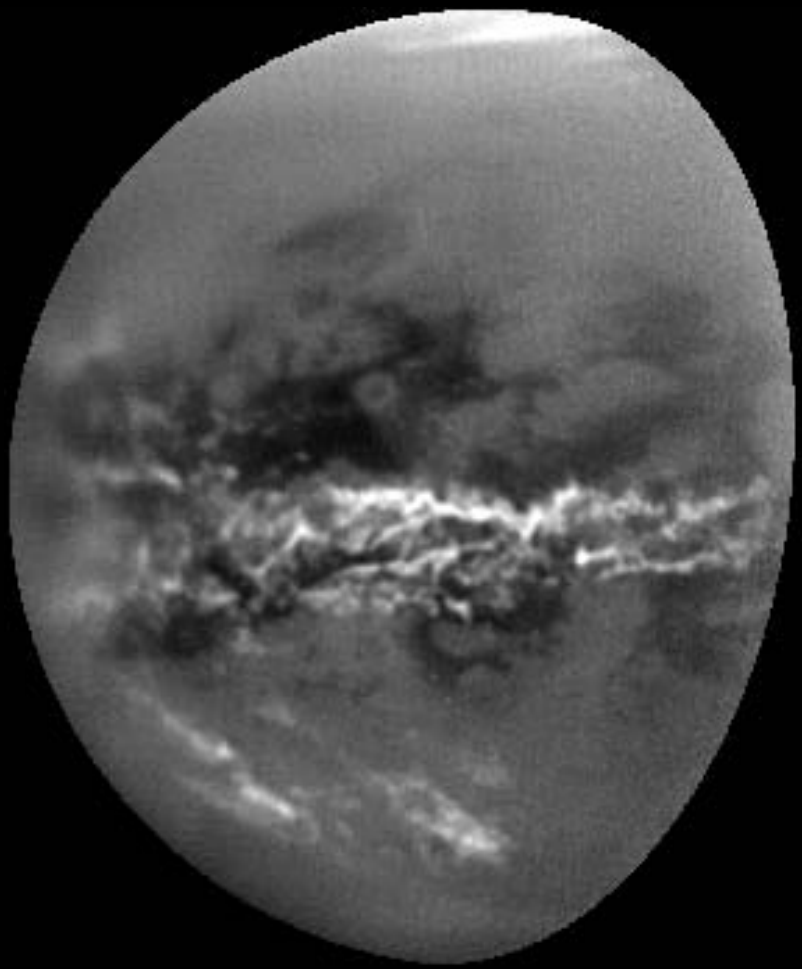
- Cassini SOI, 2 July 2004
  ≈ January 12
- 11 August 2009
  ≈ N vernal equinox
- 24 Jan 2011
  ≈ April 9
- Voyager 1 & 2
  ≈ March 29 & April 8
- May 2017
  ≈ N summer solstice

(Turtle et al., *GRL*, 2011)

Recent low-latitude cloud activity, seasonal shift in weather patterns, cf. Earth's ITCZ?



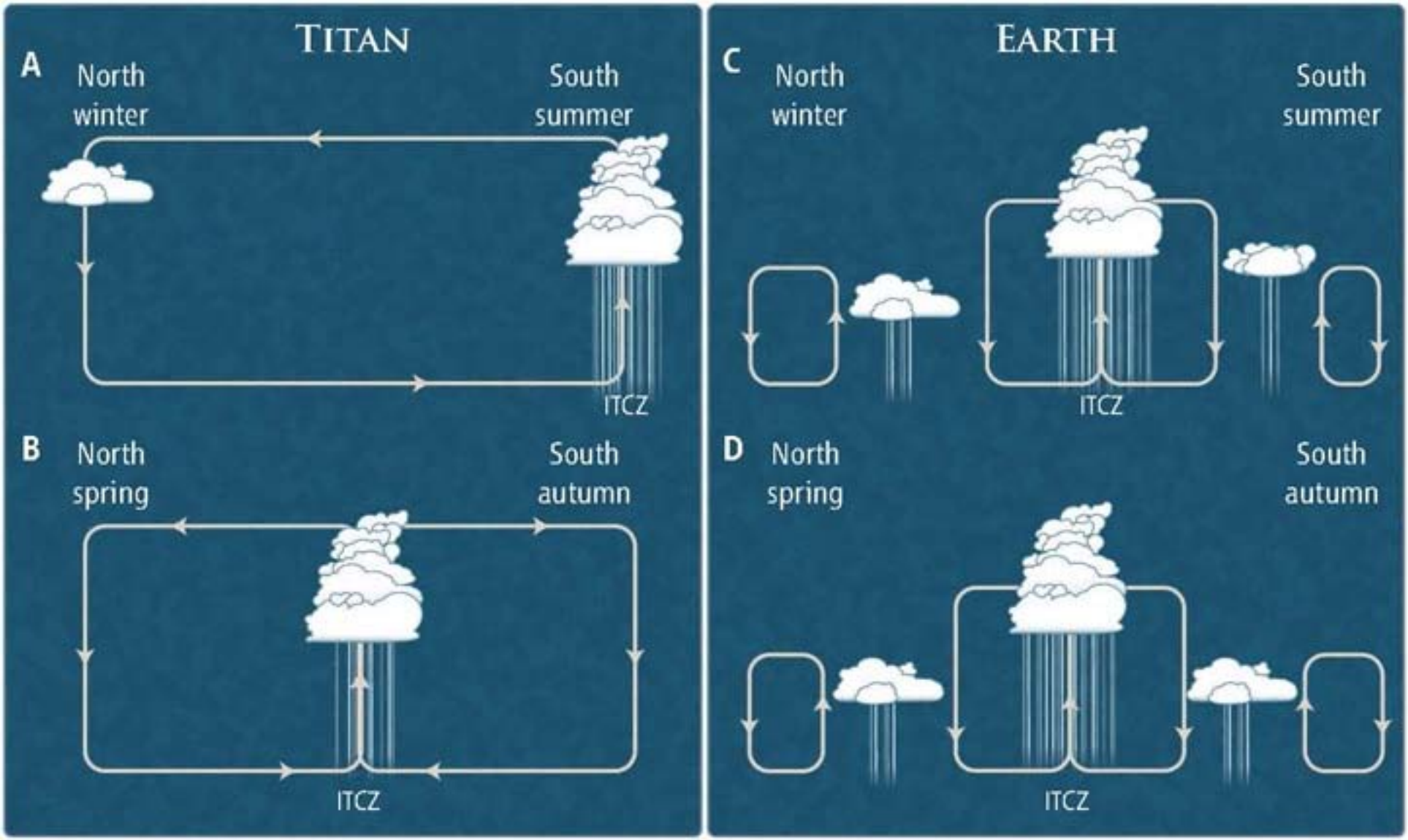
27 Sept. 2010



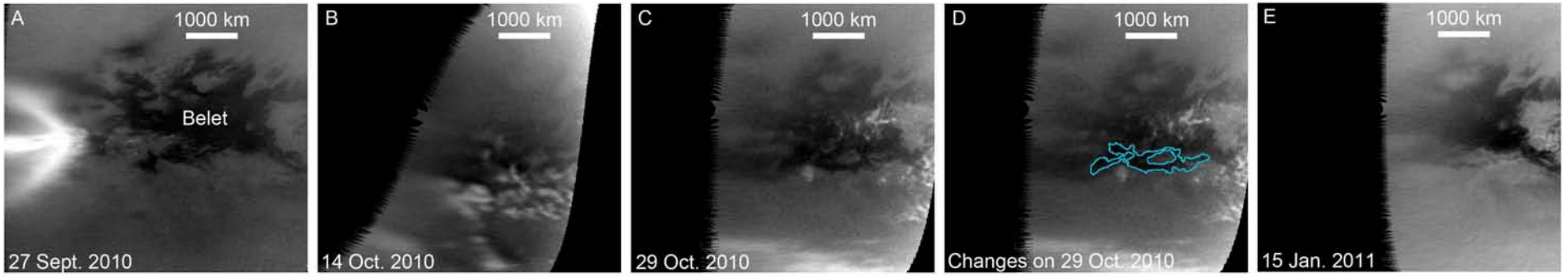
18 Oct. 2010

Turtle et al., *GRL*, 2011

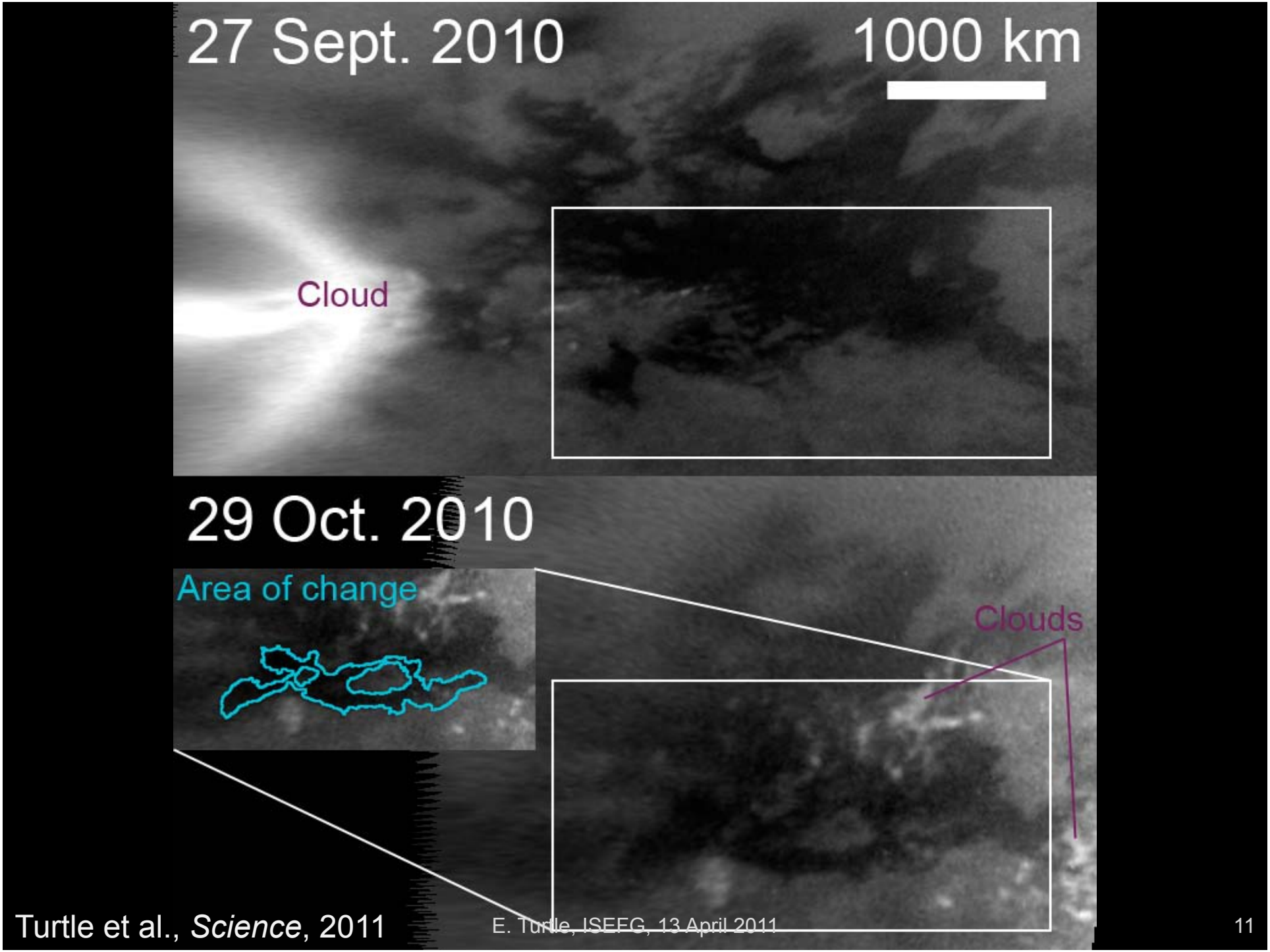
Titan's atmospheric circulation



Changes south of Belet dune field
27 Sept. 2010 - 15 Jan. 2011



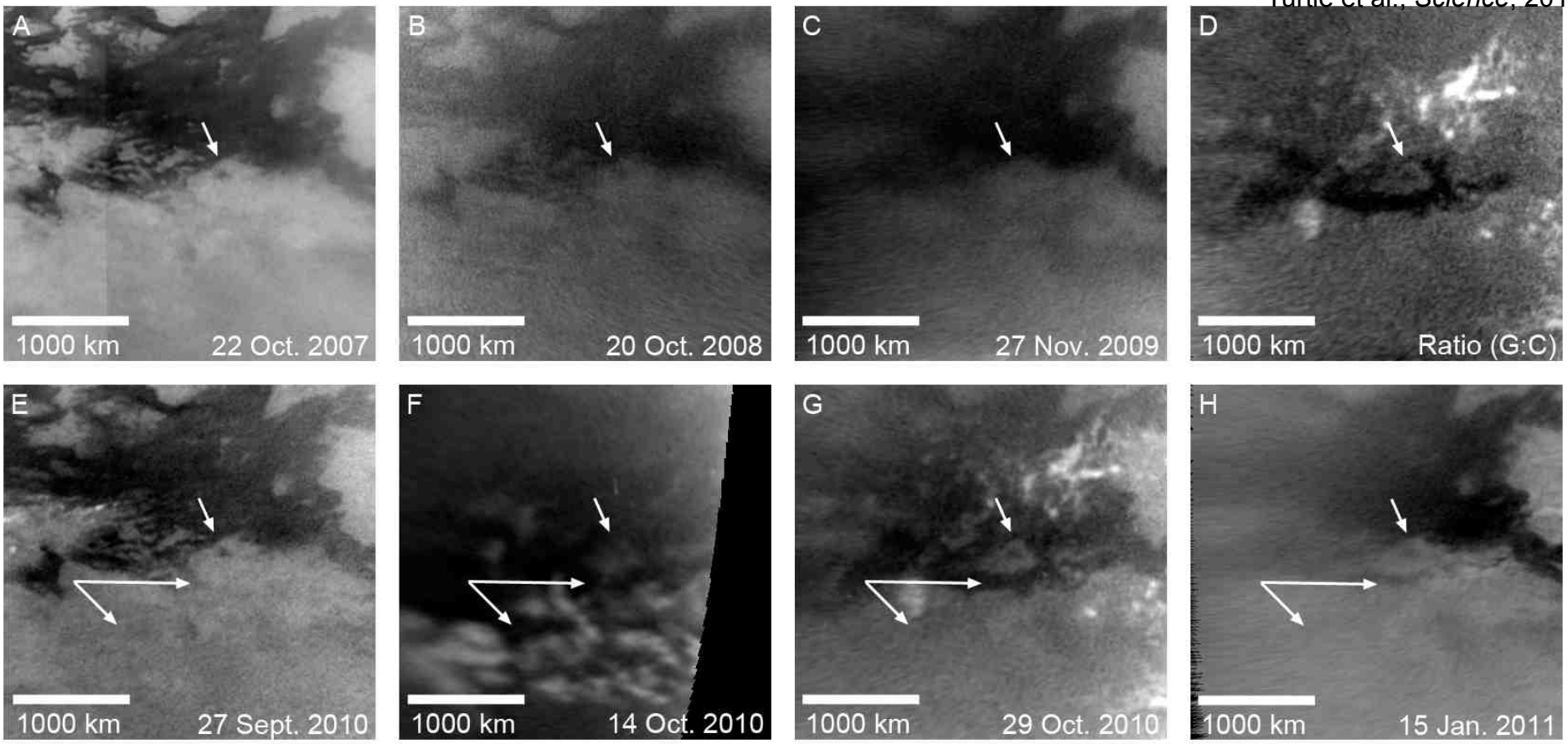
Turtle et al., *Science*, 2011



Turtle et al., *Science*, 2011

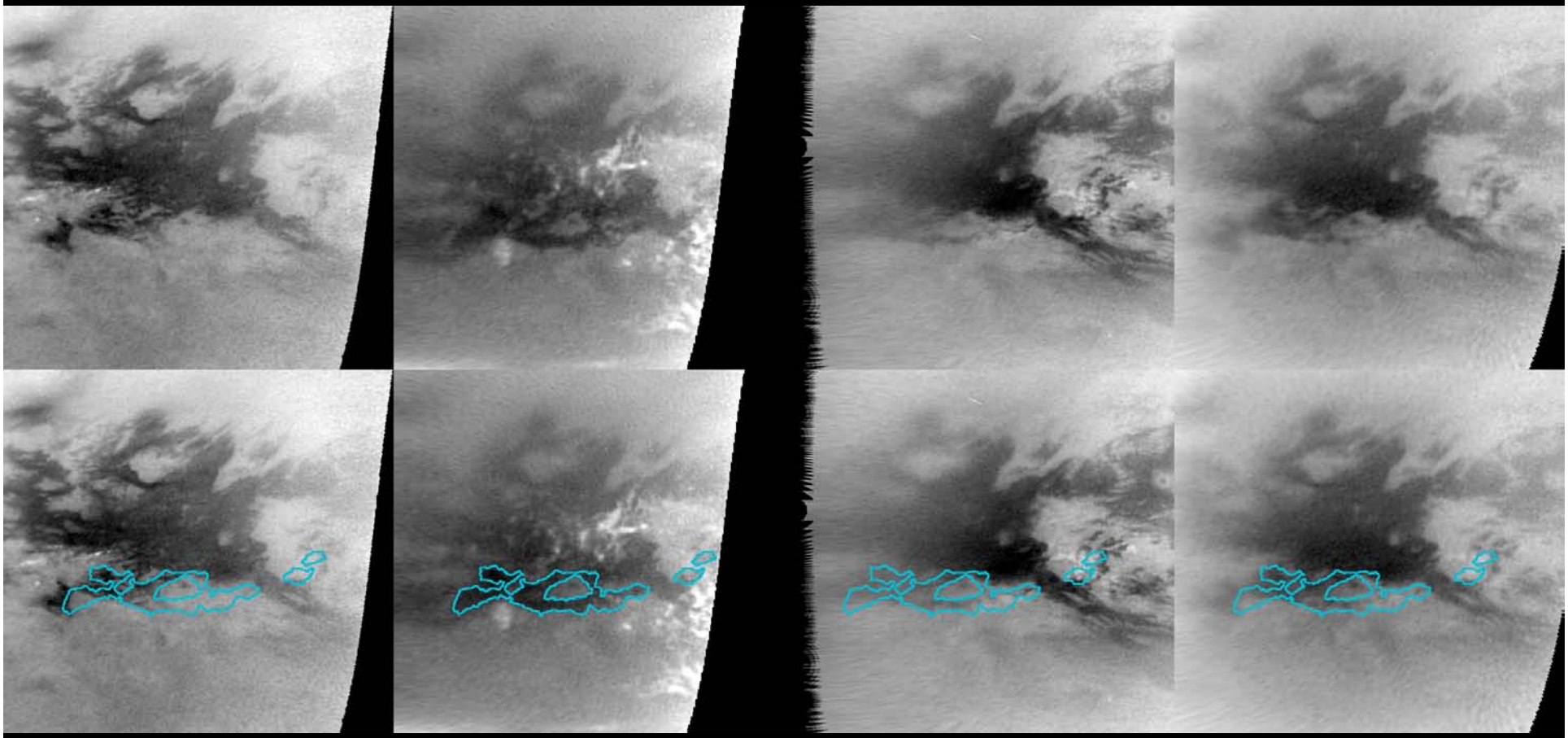
Belet region, 27 Sept. 2010 - 15 Jan. 2011

Turtle et al., *Science*, 2011

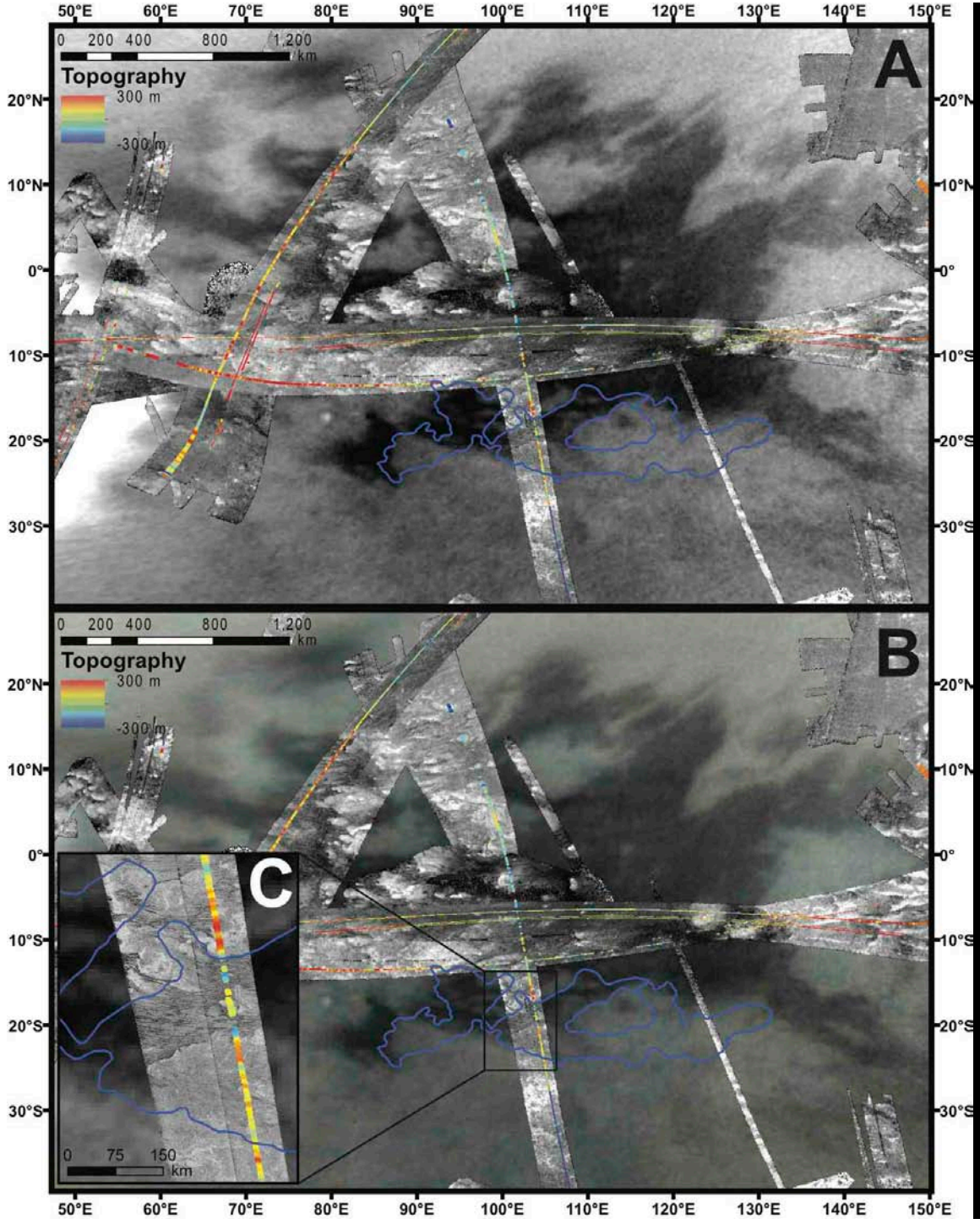


- changes extend ~2000 km east-west, ~130 km north-south
- total area >500,000 km^2 (Ligeia Mare ~ 100,000 km^2)
- subsequent brightening in some areas
- not an effect of atmosphere, viewing geometry or clouds

March 2011 observation



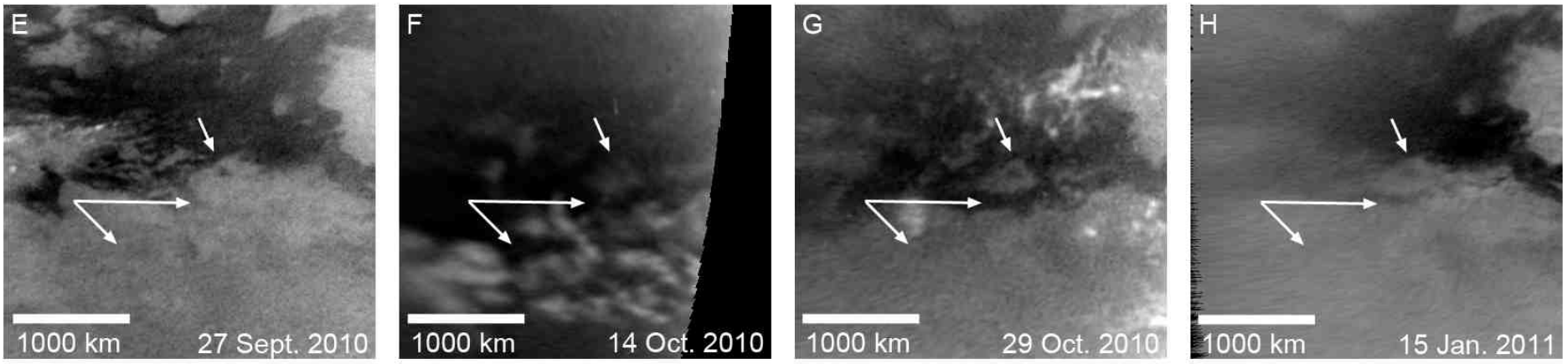
27 Sept. 2010 29 Oct. 2010 15 Jan. 2011 5 Mar. 2011



ISS, RADAR, & VIMS data

- no correlation with albedo or topographic features
- dune material nearby

Turtle et al., *Science*, 2011



- huge distance + very short timescale challenging for aeolian modification: sustained free-stream wind ≥2.2 m/s needed (Turtle et al., 2011), but unlikely (Tokano, 2010)
- cryovolcanism also unlikely: vast confined area
- need multiple events to explain areas that revert in appearance
- precipitation causing surface wetting, possibly ponding, easiest way to cover area of this scale on such a short timescale
- subsequent brightening consistent with drying (1-20 mm/week: Mitchell, 2008; Hayes et al., 2011) and/or infiltration (20 mm/week: Hayes et al., 2008)

Gemini 4 image of rain darkening in Texas

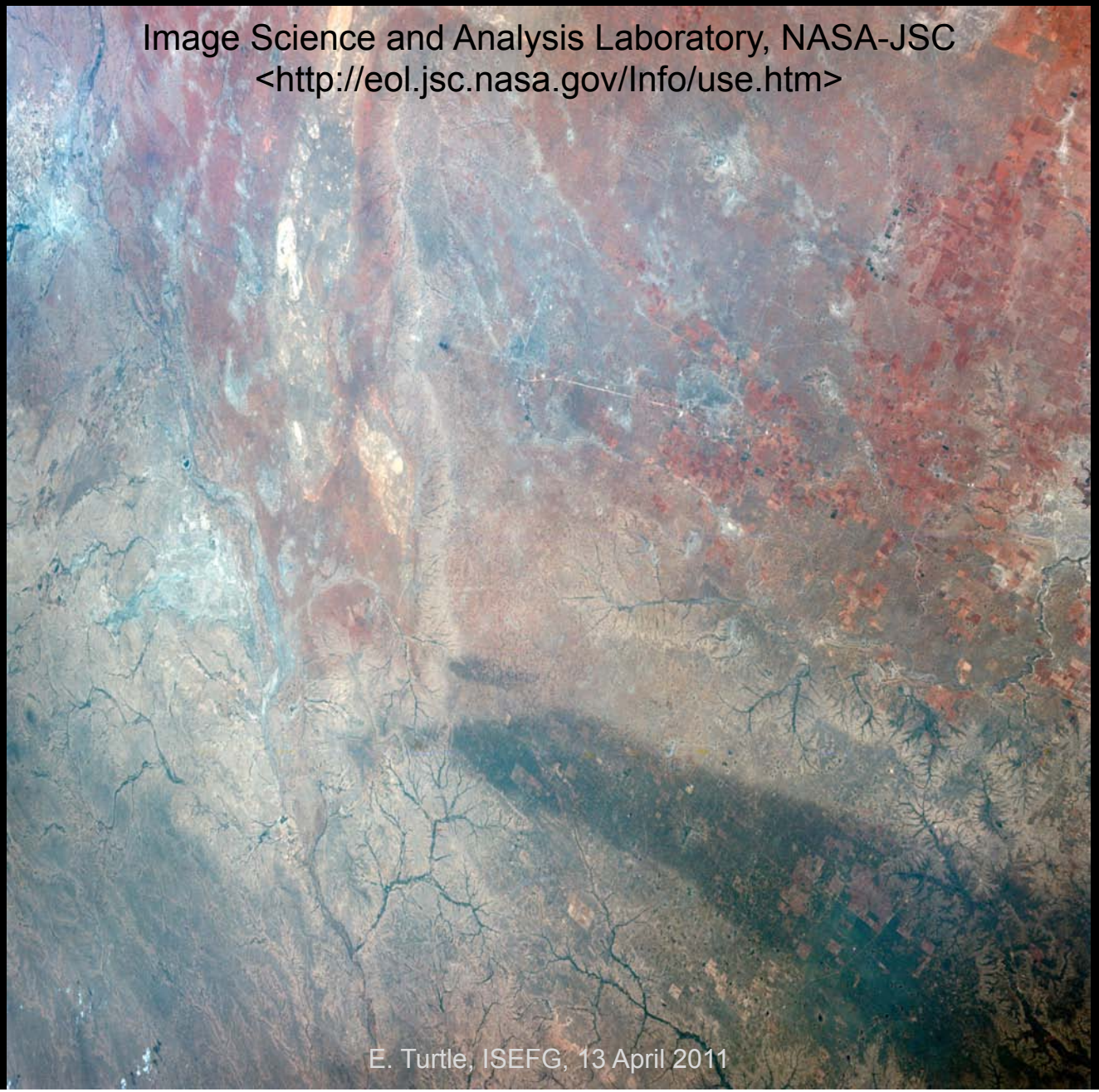


Image Science and Analysis Laboratory, NASA-JSC
<http://eol.jsc.nasa.gov/Info/use.htm>

Conclusions

- Observing shift of Titan's weather patterns (ITCZ) a little over a year after the equinox (Turtle et al., *GRL,* 2011)
  - Latitudinal preferences and seasonal changes in cloud activity suggest circulation influenced by both long radiative timescale of the atmosphere and rapid forcing by seasonal surface-temperature variations
- Storm observed in Sept. 2010 brought extensive rainfall to low latitudes, consistent with models (Turtle et al., *Science*, 2011)
- Low-latitude channels can form during rare seasonal storms sufficient to carve channels (Jaumann et al., 2008; Collins et al., 2005) between which surface dries (Mitchell, 2008) rather than being remnants of earlier climate (e.g., Griffith et al., 2008)
- Continued observations through the equinoctial season will provide essential constraints for understanding Titan's atmospheric circulation and its methane hydrologic cycle